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Experimental Study on Subgrade Soil Stabilization using Construction-Demolition Waste and Bitumen

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ABSTRACT

This study evaluates the effectiveness of stabilizing subgrade soil using construction and demolition (C&D) waste and bitumen through experimental investigation. Laboratory tests were conducted on soil samples with varying proportions of C&D waste (10%, 15%, and 20%) and bitumen (0.5%, 1.0%, and 1.5%). The California Bearing Ratio (CBR) test was used as the primary indicator of strength improvement. The results demonstrate a significant increase in CBR values from 3.2% for untreated soil to a maximum of 9.4% for stabilized mixes. The improvement is attributed to enhanced particle interlocking from C&D waste and increased cohesion due to bitumen. The optimum mix was identified as 20% C&D waste with 1.0% bitumen, which provided the highest strength. The study confirms that the combined use of waste materials and bitumen offers a sustainable and efficient solution for subgrade stabilization in pavement construction.

Keywords: Subgrade soil stabilization, Construction and demolition waste (C&D waste), Bitumen stabilization, California Bearing Ratio (CBR), Soil improvement, Waste utilization

1. INTRODUCTION

The performance of pavement structures mainly depends on the strength of the subgrade soil. Weak subgrade soils often lead to problems such as settlement, cracking, and reduced load-bearing capacity. To overcome these issues, soil stabilization techniques are used to improve the engineering properties of soil. In recent years, the use of construction and demolition (C&D) waste has gained importance as a sustainable stabilizing material. It helps in improving soil strength while also reducing environmental problems caused by waste disposal. Additionally, bitumen is used as a binding agent to enhance cohesion and water resistance in soil. This study focuses on improving subgrade soil using construction-demolition waste and bitumen through experimental tests and numerical analysis.

1.1 SOIL STABILIZATION TECHNIQUES

Soil stabilization is the process of improving the engineering properties of soil such as strength, durability, and load-bearing capacity. It is commonly used in pavement construction to enhance weak subgrade soils and ensure long-term performance.

Soil stabilization techniques are broadly classified into mechanical stabilization and chemical stabilization. Mechanical stabilization involves the addition of materials like sand, gravel, or construction-demolition waste to improve soil gradation and compaction. This method enhances density and reduces voids in the soil.

Chemical stabilization involves the use of additives such as lime, cement, and bitumen. These materials react with soil particles to increase cohesion, reduce plasticity, and improve strength. Bitumen, in particular, acts as a binding agent and provides resistance to moisture. In recent years, the use of sustainable materials like construction-demolition waste along with bitumen has gained importance. These materials not only improve soil properties but also help in reducing environmental impact and construction costs.

1.2 CONSTRUCTION AND DEMOLITION WASTE

Construction and demolition (C&D) waste consists of materials generated from building construction, renovation, and demolition activities. Common components include concrete, bricks, tiles, mortar, and other debris. With rapid urbanization, the generation of C&D waste has increased significantly, creating environmental concerns related to disposal and landfilling.

Reusing C&D waste in geotechnical applications has gained importance as a sustainable solution. When used in soil stabilization, it improves the engineering properties of soil by enhancing particle interlocking and reducing voids. The granular nature of demolition waste helps increase the strength and load-bearing capacity of subgrade soil.

Thus, the use of construction-demolition waste not only improves soil performance but also promotes environmentally friendly and cost-effective construction practices.

1.3 BITUMEN AS A STABILIZING MATERIAL

Bitumen is a viscous and adhesive material widely used in road construction. It acts as an effective stabilizing agent by binding soil particles together, thereby improving cohesion and strength. The addition of bitumen reduces water absorption and increases resistance to moisture damage. This enhances the durability and stability of the soil, making it suitable for subgrade applications. When combined with construction-demolition waste, bitumen further improves the overall performance of stabilized soil.

2. REVIEW OF LITERATURE

Ehsan Yaghoubi et al. (2024) analyzed the deformation behavior of demolition waste stabilized with bitumen. The results indicated improved resistance to permanent deformation and enhanced pavement performance. The study confirmed that bitumen-treated waste materials can be effectively used in subgrade layers.

Priyank Soni and P.K. Roy (2024) investigated the use of demolished waste concrete in soil stabilization. Their findings showed that the addition of waste concrete increased bearing capacity and reduced plasticity. The study concluded that waste concrete improves subgrade performance and reduces pavement distress.

Deshmukh et al. (2019) conducted both laboratory and finite element studies on C&D waste mixed with fly ash. Their findings showed improved strength and bearing capacity of soil. PLAXIS analysis validated the experimental results, confirming the effectiveness of the stabilization method.

Almuaythir et al. (2024 – Review Study) discussed the use of various waste materials in soil stabilization. It concluded that waste-based stabilization improves engineering properties and provides a sustainable alternative to traditional methods.

Shuvo et al. (2026) reviewed the geotechnical applications of construction and demolition waste. The authors highlighted that C&D waste improves compaction characteristics and shear strength of soil. The study also emphasized its role in sustainable construction practices.

Kumar et al. (2024) conducted a review on the use of plastic waste in soil stabilization. The study highlighted that waste materials can significantly improve soil strength, reduce plasticity, and enhance durability. It emphasized the importance of recycling waste materials in geotechnical engineering. The findings support the use of alternative materials like demolition waste for sustainable stabilization practices.

2.2 RESEARCH GAP

From the literature review, it is observed that many studies have focused on soil stabilization using either construction-demolition waste or bitumen individually. However, limited research has been conducted on the combined effect of both materials on subgrade soil stabilization.

Furthermore, the integration of experimental results with numerical modeling using PLAXIS 2D has not been extensively explored. Therefore, this study aims to investigate the combined use of construction-demolition waste and bitumen through both laboratory testing and numerical analysis to provide a comprehensive understanding of soil stabilization.

2.3 OBJECTIVES OF THE STUDY

The Objectives of this study are as follows,

❖ To evaluate the engineering properties of unstabilised collected soil sample.

❖ To study the combined effect of demolition waste and bitumen on the strength and deformation behaviour of subgrade soil.

❖ To determine the optimum mix proportion of soil–demolition waste–bitumen based on laboratory test results.

❖ To study changes in compaction characteristics (OMC and MDD) due to the addition of demolition waste and bitumen.

❖ To model the behaviour of unstabilised and stabilised subgrade soil in PLAXIS 2D using the results obtained in the laboratory.

3. MATERIALS AND METHODOLOGY

The materials used and the methodology adopted for the experimental investigation of subgrade soil stabilization using construction-demolition waste and bitumen. The properties of the materials such as soil, demolition waste, and bitumen are studied through standard laboratory tests.

3.1 MATERIALS USED

The materials used in this study include subgrade soil, construction and demolition (C&D) waste, and bitumen. These materials are selected to evaluate their effectiveness in improving the engineering properties of soil.

3.1.1 Subgrade Soil

Soil samples were collected dried in air for 24 hours and then the lumps are powdered to obtain the index properties as well as the engineering properties of the sample shown in table 1.

Table: 1 Properties of soil sample

S.NO	PROPERTY	VALUES
1.	Specific gravity (Gs)	2.65
2.	Moisture content	24 %
3.	Liquid limit (W_L)	48 %
4.	Plastic limit (W_P)	25 %
5.	Plasticity index (PI)	23 %
6.	Optimum moisture content (OMC)	18 %
7.	Maximum dry density (MDD)	1.72 g/cc
8.	Unconfined compressive strength (qu)	48 kN/m^2
9.	Cohesion (c)	24 kN/m^2

3.1.2 Construction and Demolition Waste

Construction and demolition waste consists of materials such as crushed concrete, bricks, and tiles obtained from demolition sites. The collected waste is crushed and sieved to obtain uniform particle size. This material is used as a stabilizing agent to improve soil strength by enhancing particle interlocking and reducing voids.

Fig 1: Construction and Demolition Waste

3.1.3 Bitumen

Bitumen is used as a binding material in this study. It improves the cohesion between soil particles and provides resistance to moisture. The bitumen used is of suitable grade for stabilization purposes, and its basic properties are considered during the experimental work.

Fig 2: Bitumen Sample

Table: 2 Properties of bitumen

S.NO	PROPERTY	VALUES
1.	Penetration test	32.1 mm
2.	Softening point	42.3°
3.	Ductility test	56 cm
4.	Viscosity test	50 sec

3.2 EXPERIMENTAL METHODOLOGY FLOWCHART

The figure 3 illustrates the step-by-step procedure adopted in the study. It represents the systematic approach followed to evaluate the effectiveness of construction-demolition waste and bitumen in soil stabilization.

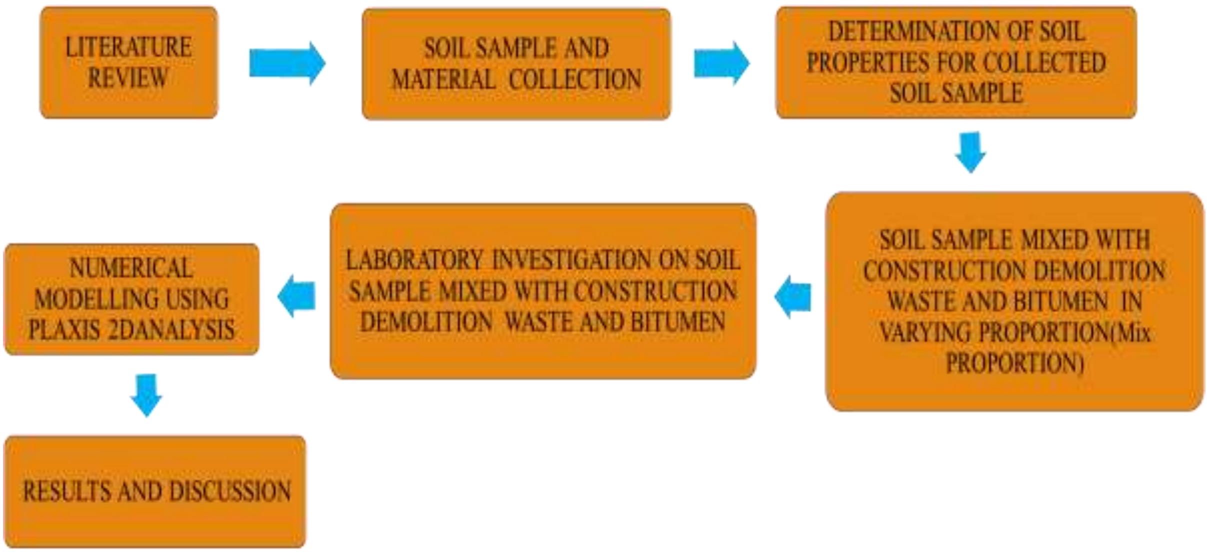

Fig 3: Experimental Methodology Flowchart

4. EXPERIMENTAL STUDY

The experimental investigations carried out to evaluate the engineering properties of subgrade soil stabilized with construction-demolition waste and bitumen. The objective of the experimental study is to determine the compaction characteristics and strength behavior of the soil. Standard Proctor Compaction tests are performed to obtain the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), followed by California Bearing Ratio (CBR) tests to assess the load-bearing capacity of each mix. The results obtained from these tests are analyzed and compared to identify the optimum mix that provides maximum strength improvement.

4.1 MIX PROPORTIONS OF MATERIALS

The table 4 shows each mix is prepared thoroughly to ensure uniform distribution of materials before conducting laboratory tests. These proportions are selected to identify the optimum combination that provides maximum strength and stability for subgrade soil.

Fig 4: Soil sample mixed with demolition waste and bitumen

Table 4: Testing Plan for Mix Proportions

Mix ID	Soil (g)	Demolition Waste (%)	Demolition Waste (g)	Bitumen (%)	Bitumen (g)
C0	2500	0	0	0	0
C01	2500	10	250	-	-
C02	2500	15	375	-	-
C03	2500	20	500	-	-
C1	2500	10	250	0.5	12.5
C2	2500	10	250	1.0	25.0
C3	2500	10	250	1.5	37.5
C4	2500	15	375	0.5	12.5
C5	2500	15	375	1.0	25.0
C6	2500	15	375	1.5	37.5
C7	2500	20	500	0.5	12.5
C8	2500	20	500	1.0	25.0
C9	2500	20	500	1.5	37.5

4.2 STANDARD PROCTOR COMPACTION TEST

The Standard Proctor Compaction Test is conducted to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of both untreated soil and stabilized soil mixes. This test helps in understanding the compaction characteristics of soil when mixed with construction-demolition waste and bitumen.

The test is carried out as per standard procedures by compacting the soil sample in a mould at different moisture contents using a standard hammer. For each mix (C0 to C9 and additional mixes with only demolition waste), the dry density is calculated and plotted against moisture content to obtain the compaction curve. From this curve, the OMC and MDD values are determined.

Fig 5: Standard proctor test

4.2.1 Determination of Optimum Moisture Content (OMC) and Maximum Dry Density (MDD)

The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are determined from the Standard Proctor Compaction test results. A graph is plotted between moisture content and dry density for each soil mix. The compaction curve obtained shows an initial increase in dry density with moisture content, reaching a peak value, and then decreasing with further increase in moisture.

The peak point of the curve represents the Maximum Dry Density (MDD), and the corresponding moisture content at this point is known as the Optimum Moisture Content (OMC). At OMC, the soil particles are optimally lubricated, allowing them to rearrange into a denser configuration under compaction.

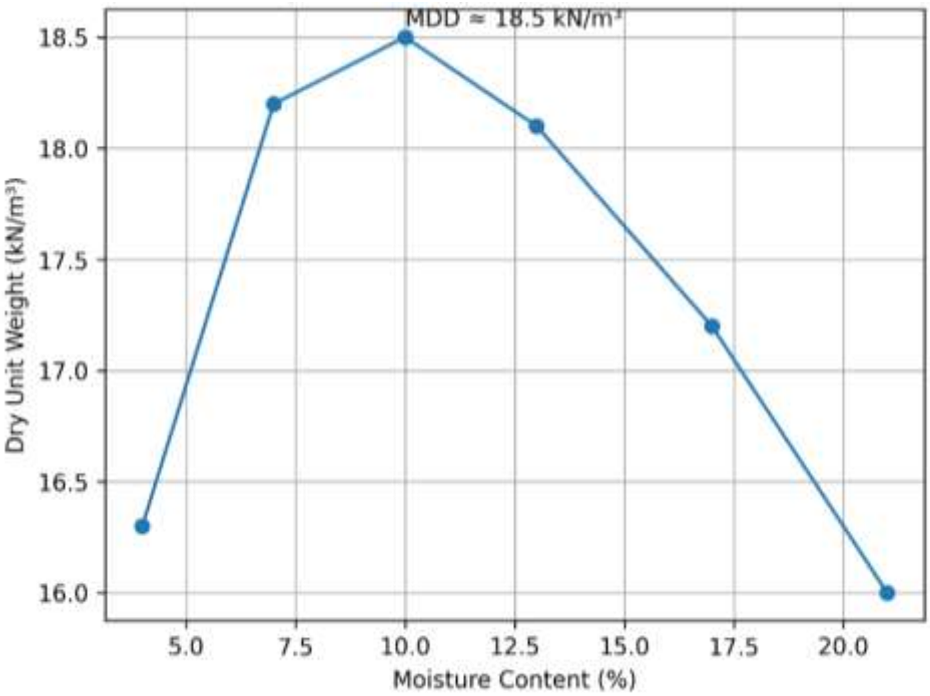

Fig 6: Compaction Curve for Mix C5 (15% Demolition Waste + 1.0% Bitumen

The figure 6 represents the relationship between moisture content (%) and dry density (g/cc) for mix C5 consisting of 15% demolition waste and 1.0% bitumen. It can be observed that the dry density increases with an increase in moisture content up to a certain point, after which it starts decreasing.

The peak point of the curve indicates the Maximum Dry Density (MDD), which is approximately 1.85 g/cc, and the corresponding moisture content represents the Optimum Moisture Content (OMC), which is about 10%.

This behavior occurs because water initially helps in lubrication and better compaction of soil particles. However, excess water beyond the optimum level leads to a reduction in dry density due to increased pore water pressure and reduced inter-particle contact.

Table 5: OMC & MDD Values

Mix ID	Demolition Waste (%)	Bitumen (%)	OMC (%)	MDD (g/cc)
C0	0	0	12.5	1.72
C01	10	0	11.8	1.75
C02	15	0	11.2	1.78
C03	20	0	10.7	1.80
C1	10	0.5	11.5	1.77
C2	10	1.0	11.0	1.79
C3	10	1.5	10.8	1.76
C4	15	0.5	10.9	1.81
C5	15	1.0	10	1.86
C6	15	1.5	10.2	1.80
C7	20	0.5	10.4	1.83
C8	20	1.0	10.0	1.85
C9	20	1.5	9.8	1.82

4.3 CALIFORNIA BEARING RATIO (CBR) TEST

The California Bearing Ratio (CBR) test is conducted to evaluate the load-bearing capacity of both untreated and stabilized soil samples. In figure 7 shows CBR Test Setup for Stabilized Soil Sample The test is performed on specimens prepared at their Optimum Moisture Content (OMC) and Maximum Dry Density (MDD).

Fig 7: CBR Test Setup for Stabilized Soil Sample

The CBR value is determined as the ratio of the load carried by the soil sample to the standard load at a specified penetration. It is an important parameter for assessing the suitability of soil as a subgrade material in pavement design.

The results show that the addition of demolition waste and bitumen improves the CBR value, indicating enhanced strength and stability of the soil. The maximum CBR value is obtained at the optimum mix proportion.

4.4 RESULTS AND DISCUSSION

The results of the California Bearing Ratio (CBR) test are presented in Figure 8, which shows the variation of CBR values for different soil mixes. The untreated soil (C0) exhibits a low CBR value of 3.2%, indicating poor load-bearing capacity and the need for stabilization.

With the addition of construction and demolition (C&D) waste alone (C01–C03), the CBR value increases progressively from 4.5% to 6.5% at 20% replacement. This improvement is mainly due to enhanced particle interlocking, reduced plasticity, and improved load distribution resulting from the granular nature of demolition waste.

Further improvement is observed when bitumen is added to the soil–waste mixtures (C1–C9). The CBR value reaches a maximum of 9.4% for mix C5 (15% C&D waste + 1.0% bitumen). This increase is attributed to the binding action of bitumen, which enhances cohesion between particles and reduces moisture susceptibility, thereby improving strength and stability.

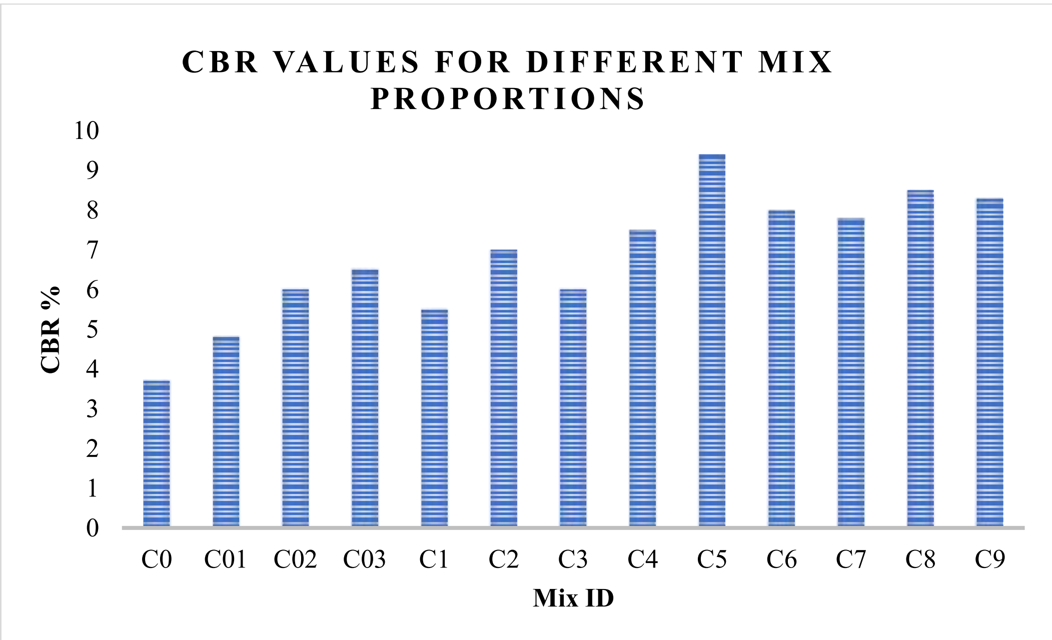

Fig 8: CBR Values for different mix proportions

The bar chart clearly illustrates a consistent increase in CBR values with increasing stabilizer content up to the optimum level. However, a slight decrease in CBR is observed at higher bitumen content (C9: 1.5%), due to excess coating and lubrication effect, which reduces particle contact and weakens interlocking.

Overall, the combined use of C&D waste and bitumen significantly improves the strength of subgrade soil by enhancing both frictional resistance and cohesion. The optimum mix proportion is identified as 15% C&D waste with 1.0% bitumen, which provides maximum strength and stability.

5. CONCLUSIONS

An untreated soil has a low California Bearing Ratio (CBR) of 3.2% and therefore has a low load bearing capacity. The untreated soil must be stabilized before it will provide acceptable load-bearing capacity. When C&D waste material (construction and demolition debris) is added to the untreated soil, the soil strength improves, and the CBR increased to 6.5% with a 20% C&D replacement. The inclusion of bitumen adds cohesion and reduces the effects of moisture on the soil. The optimum C5 mix for producing the highest CBR is 15% C&D waste and 1.0% bitumen, which provides a CBR of 9.4%.

After 1.0% bitumen, the CBR begins to slightly decrease because the bitumen has changed the particle interaction within the soil. The total combined stabilization method has increased strength to the untreated soil; therefore, it is suitable for use as subgrade material. Use of this combined stabilization method also promotes sustainable construction through the use of waste material and reduction of negative environmental impact and construction costs.

REFERENCES

1. Arulrajah, A., Yaghoubi, E., Wong, Y. C., & Horpibulsuk, S. (2020). Recycled waste materials in geotechnical engineering applications. *Transportation Geotechnics*, 22, 100298.

2. Disfani, M. M., Arulrajah, A., Bo, M. W., & Sivakugan, N. (2020). Shear strength behavior of recycled construction materials. *Construction and Building Materials*, 236, 117543.

3. Shirin, M. S., Islam, M. M., & Kumruzzaman, M. (2020). Stabilization of coal mine waste for subgrade applications. *American Journal of Traffic and Transportation Engineering*, 5(5), 51–56.

4. Solanki, P., & Zaman, M. (2021). Microstructural and strength characteristics of stabilized soils. *Journal of Materials in Civil Engineering*, 33(4), 04021012.

5. Estabragh, A. R., Parsaei, B., & Javadi, A. A. (2021). Experimental investigation of stabilized clayey soils. *Arabian Journal of Geosciences*, 14(5), 1–12.

6. Tourchi, S. (2021). Experimental study on deformation behavior of soils. *Soils and Foundations*, 61(5), 1345–1358.

7. Arulrajah, A., Disfani, M. M., Horpibulsuk, S., & Suksiripattanapong, C. (2021). Engineering properties of recycled aggregates in pavement applications. *Journal of Cleaner Production*, 278, 123984.

8. Guo, H., & Hu, X. (2021). Strength characteristics of construction waste stabilized soil. *Journal of Cleaner Production*, 323, 129122.

9. Sabat, A. K., & Moharana, A. K. (2022). Effect of industrial waste on soil stabilization. *International Journal of Geotechnical Engineering*, 16(2), 189–198.

10. Pereira, P. M., & Vieira, C. S. (2022). Use of recycled construction materials in pavement layers. *Sustainability*, 14(21), 13918.

11. Kumar, R., Gupta, S., & Sharma, M. (2022). Experimental study on soil stabilization using waste materials. *Environmental Engineering Research*, 27(4), 210–220.

12.Taha, R., Al-Harthy, A., & Al-Shamsi, K. (2022). Performance of recycled asphalt materials in road bases. *Construction and Building Materials*, 315, 125689.

13.Gupta, A., Singh, A., Kumar, S., & Shukla, S. (2023). Soil stabilization using construction and demolition waste. *International Journal for Research in Applied Science & Engineering Technology*, 11(5), 55834.

14.Geckil, T., Guneyisi, E., & Gesoglu, M. (2023). Mechanical properties of stabilized soils with recycled materials. *Materials*, 16(7), 2456.

15.Bharti, S., Sangale, A., & Roham, C. (2023). Utilization of waste materials in soil stabilization. *Results in Engineering*, 18, 101234.

16.Guo, H., Zhang, Y., & Hu, X. (2023). Experimental investigation of recycled construction materials in subgrade stabilization. *Journal of Cleaner Production*, 385, 135678.

17.Arulrajah, A., Yaghoubi, E., & Disfani, M. M. (2024). Sustainable stabilization of pavement materials using recycled waste. *Transportation Geotechnics*, 40, 100876.

18.Agate, E., Kouassi, P., & Yao, K. (2024). Stabilization of expansive soils using waste-based materials. *Construction and Building Materials*, 362, 129785.

19.Yaghoubi, E., Arulrajah, A., & Disfani, M. M. (2024). Bitumen-treated recycled materials for pavement applications. *Road Materials and Pavement Design*, 25(2), 455–470.

20.Almuaythir, F. (2024). Sustainable soil stabilization using waste materials: Experimental review. *Sustainability*, 16(3), 1125.

21.Sridhar, H. N., Kumar, G. S., & Pandit, P. (2025). Enhancing lateritic soil properties using industrial waste. *Discover Materials*, 6, 5.

22.Kafle, B., & Baghbani, A. (2025). Sustainable soil stabilization using waste sludge: Experimental evaluation. *Sustainability*, 17(21), 9919.

23.Setiawan, A. F., Rahadian, E., Firuliadhim, G., & Wintoro, B. (2025). Expansive soil stabilization using lime and bottom ash. *Potensi: Jurnal Sipil Politeknik*, 27(2), 47–57.